U.S. DEPARTMENT OF ENERGY
SOLAR DECATHLON

2021 Design Challenge
Office Building

Harvard University
Graduate School of Design

ResilientHub

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Project summary

In this era of Anthropocene, buildings will be subjected to rising temperatures and increased risk of natural disasters. In addition, a growing population and strong urbanization trend will increase the density of our cities. These environmental changes will have a considerable effect on future building performance. ResilientHub, situated in the Seaport District of Boston, Massachusetts, USA, is a future-ready building that maintains the highest energy efficiency and occupant comfort level possible throughout its lifetime.

The proposed building design accommodates thirteen floors office space, in addition to retail, restaurants, a daycare center for children of office employees, and underground parking on the lower floors. The office floors are expected to cater to a diverse range of corporate users from the life sciences, technology and financial sector. Adaptable ETFE pillow façades optimize solar heat gain and daylight access in response to daily and seasonal weather changes, and future global warming and urbanization. A solar chimney, placed prominently at its most optimal position for solar heat gain, provides buoyancy-driven natural ventilation and significantly lowers the building's cooling loads with future rising temperatures. A series of indoor atria supply the office spaces with a healthy level of natural daylight, and provide a space for informal social interaction. Situated in a flood zone, the building employs building and landscape-integrated strategies to mitigate flood levels and delay, resist and discharge flood water. The innovative, high-performance design solutions ResilientHub employs are directly applicable to the vast majority of the future global building stock that will be affected by the same environmental changes.

Design strategy

In order to maximize the building's energy efficiency and comfort level, and ensure its resilience to urban development, climate change and flooding, its performance was tested on a 2025-2080 future environmental development scenario. Both active and passive, and conventional and innovative building systems were subjected to comprehensive simulation-based performance analyses, and subsequently, the most appropriate ones were selected for implementation. The novel design paradigm was combined with a holistic design approach to balance the need for these building systems with desired economic returns, occupant needs, neighborhood enhancement and ecological benefits.

Project data*

- Boston, MA, USA | Climate zone 5A
- Plot size: 21,000 ft^2 (0.5 acres)
- Gross floor area: 230,000 ft^2
- Number of stories: 13
- Occupancy: 250 gross ft^2 / person
- Source EUI: 27.50 kBtu/ft^2 | Site EUI: 9.82 kBtu/ft^2
- Utility cost: $ 13,165 / month
- Construction cost: $ 200 million | 683 $/ft^2
- IRR: 21.7%
- Average daylight autonomy (excl. core): 78%

*All data, except the total cost, apply to the office section of this building

Technical specifications*

	U**	SHGC	Tvis
• Curtain wall	0.02		
• Windows (NE and NW):	0.03	0.60	0.75
Windows (SE and SW):	0.33	0.18-0.47	0.32-0.47

- HVAC: Variable refrigerant flow heat pump system with closed-loop water-to-water ground source heat pump, COP of 1.2-4.2
- Artificial lighting: LED ceiling-recessed luminaire, 29.0 W, 0.13 W/ft^2/100 lx
- Renewable energy generation: 1,217,095 kBtu / year

**in Btu/(h•ft^2•°F)

Project highlights

Architecture The geometry of ResilientHub, most notably its optimized sloped roof and tapered solar chimney, clearly demonstrate the methods employed for low-energy building performance. Located at the intersection of two major arteries of Boston Seaport, the innovative and iconic design of the building serves as a proxy for future environmentally-conscious building design.

Engineering The design of the building provides a high daylight autonomy in the work spaces. When natural daylight is not sufficiently available, lighting levels are maintained with non-mercury LED pendant luminaires and ceiling recessed LEDs.

Market analysis Development returns were slightly reduced due to design measures taken to improve energy efficiency and comfort standards. However, roughly 60% of added costs are offset by property value gains due to reduced annual operating expenses. Upon stabilization in 2024, the project is expected to earn 21.7% IRR to its equity investors.

Durability and resilience In anticipation of the looming environmental changes it will experience, ResilientHub employs an adaptable ETFE pillow façade that modulates solar heat gain in response to global warming and urbanization. To further mitigate the effects of rising temperatures, a solar chimney naturally ventilates the building, saving more energy for cooling than wind-driven ventilation. Flood protection is achieved by pervious landscaping to delay floods, flood water collection in the lowest basement level to mitigate the flood level, landscaping and movable barriers to block flood water, and building systems to facilitate the removal of flood water.

Embodied environmental impact The building's hybrid structure of a wooden core, steel frame and cross-laminated timber (CLT) panels reduces the embodied environmental impact of the building's structure by 55% compared to traditional office building structure. The building's environmental impact is further reduced by the implementation of ETFE pillows on two building faces, which have a roughly 50% lower impact per ft^2 of façade than standard double glass. The other façades use triple-pane glazed windows with wood spandrel that have 28% lower embodied carbon values than typical façades.

Integrated performance The carefully shaped building volume and indoor south-facing atria balance the need to maximize rentable floor area, for a sufficient level of work space daylight autonomy, and for public space enhancement. A south-facing, 30-degree sloped roof maximizes solar heat gain in the solar chimney as well as electricity yields of photovoltaics on the roof.

Occupant experience The main design feature enhancing occupant experience is the series of south-facing indoor atria. The size and shape of the atria were optimized to meet a sufficient daylight autonomy in the work spaces. Atria inside the building provide a flexible space for breaks, informal collaboration, and lectures. Custom-designed movable partitions with planters provide greenery and create a healthy work environment. Views to exterior and into the atria further boost mental health. An on-site daycare facility will help women gain equitable access to the workforce.

Comfort and environmental quality A buoyancy-driven natural ventilation system stimulated by a solar chimney cools the building and provides fresh air. A decentralized HVAC system of air handling units on each office floor provides heating, cooling and ventilation when the weather doesn't allow for natural ventilation. During heating hours, heat is recovered from exhaust air at the top of the solar chimney.

Energy performance The adaptable ETFE pillow façade responds to weather conditions in real-time and reduces the building's heating and cooling load. The solar chimney further reduces the building's cooling load. Both systems save a significant amount of energy over the building's lifetime. A ground source heat pump reduces the energy required for heating and cooling. Renewable energy is generated on the optimally angled roof and on exterior solar shading.

Presentation A 2025-2080 scenario for local urban development around the plot, rising temperatures due to global warming and flood risk is used to both frame the design problem and describe the performance of the building systems that ResilientHub employs over the course of its lifetime.